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Original Article

BIOGAS PRODUCTION FROM SERICULTURE WASTEWATER AS FEED STOCKS IN BATCH PROCESS USING RUMEN FLUID

S. PRIYANGA[1], P. T. RAMESH[1], M. MAHESWARI[1] & S. KARTHIKEYAN[2]

[1] *Department of Environmental Sciences, TNAU, Coimbatore, Tamil Nadu, India*

[2] *Department of Renewable Energy Engineering, TNAU, Coimbatore, Tamil Nadu, India*

ABSTRACT

The present investigation was carried out to explore the biogas production potential from liquid and solid wastes arising from the sericulture industry. Batch studies conducted using silk reeling waste substrates that were mixed in suitable proportions to have 8% TS and inoculated with rumen fluid @5% as starter inoculums revealed that the specific biogas production (L/Kg of feed) for all types of sericulture wastes was found to be around 0.11 (L/Kg/day). Among the different substrate combinations tested, silk reeling wastewater mixed with feed waste in the ratio of 1:0.3:0.05 showed best results with higher gas production of 2.94 (L/Kg/day) and a methane content of 67per cent. The biogas production in other sericulture wastes mixed with silk reeling wastewater varied from 2.38 (L/Kg/day) to 2.65 (L/Kg/day), indicating the potentiality of biogas production from sericulture industry wastes.

***KEYWORDS:** Sericulture, Silk Reeling Wastewater, Rearing Unit Wastes, Biogas & Methane*

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INTRODUCTION

Methanogenesis is a process of anaerobic digestion of organic materials to yield methane. The feedstock used for biogas production may be solid, concentrated or dilute liquids and slurries. The major feedstock for biogas production arises out of agricultural activities and allied industrial units. Sericulture is an export oriented agro-based industry. India is the second largest raw silk producing country with an annual production of 31,931 MT ("Central silk board, Department of Sericulture, Government of Tamil Nadu," 2017), fetching Rs.1,280 crores per annum from silk exports. During the production of silk fibre, considerable quantity of wastewater is generated from silk reeling units. It was estimated that 1,000-3,000 m^3 of wastewater is being generated per day for every 12-20 tonnes of silk fabric production (Akter, 1998). Silk reeling waste water is organic, pale yellow to brown in colour, jellylike, putrid, rich in protein and contains dead pupae (Li, 2015). The effluent from the silk industry have the characteristics of alkaline pH (7.39-7.93);Chemical Oxygen Demand (COD) 480-875 mg/L; Biological Oxygen Demand (BOD) 338-1869 mg/Land Total Dissolved Solids (TDS)437.64 - 628.73 mg/L (Sittitoon, 2015). (Patwardhan, 2017)reported that, with an average total solid content of 4000 mg/L and a COD: BOD ratio of 2.5: 2.9, silk reeling wastewater could be treated by anaerobic treatment to produce biogas. Silk reeling wastewater is also rich in protein, called sericin, arising largely from cocoon waste. Sericin constitutes about 20-30% of the total cocoon weight (Małgorzata, 2017). In India, 250-300 tons of sericin could be discharged in silk reeling wastewater for about 1600 tons of silk fabric production per year (More, 2013).

Not only liquid waste, but solid wastes in the form of feed waste, cocoon waste and excreta are generated during rearing of silkworm. For, 100 dfls (disease free layings) consuming 1000 kg of mulberry leaves, approximately 300 kg of litter (excreta) and 500 kg of unused (left over) mulberry feed waste comprising dried leaves, veins of leaves and leaf stalk are generated(Prabhakar, 1985)

Organic waste with high total solid content can be exploited for biogas production. Agro industrial wastes such as wheat straw (82.9%), chicken litter (77.2%) and food waste (27.9%) have high total solid content could be used for anaerobic digestion (Zahan, 2017). Sericulture wastewater, though low in total solids, when combined with TS rich solid waste arising out of mulberry reeling units and inoculated with starter cultures, can be exploited for biogas production. The anaerobic bacteria that are abundantly present in the rumen of ruminants could be used as starter cultures to induce methanogenesis in organic substrates. Cattle rumen fluid alone could generate biogas production of 386 cm^3 in 20 days of the batch experiment, as revealed by (Bello, 2019). (Nakai, 2013)reported that, addition of rumen fluid with waste paper increased the methane content of 73.4 per cent. Rumen fluids, a rich store house of anaerobic organisms is abundantly present in the rumen of the ruminants and that rumen is always thrown away as wastes from abattoirs.

Keeping this in view, silk reeling wastewater, cocoon waste, feed waste and excreta waste were taken as a substrate in this study aiming to generate biogas from different sericulture wastes.

MATERIALS AND METHODS

The silk reeling wastewater was collected from a silk reeling unit in Coimbatore, stored in cold room at 4^0C and characterized for various properties. Silkworm excreta and feed waste were collected from two mulberry rearing farms in Avinashi and Udumelpet of Tiruppur district, Tamil Nadu.

Total solids, volatile solids and Fixed carbon in the test substrates were determined adapting standard procedures (APHA, 1998). Totalkjeldahl nitrogen was determined by automatic distillation (Jackson, 1985); Organic carbon content obtained by titration with 0.5 N FAS after digestion with H_2SO_4(Sommers, 1998). C/N ratio was found by separately estimating the total organic carbon and Totalkjeldahl nitrogen.

Anaerobic digestion was done in 300 ml of glass saline bottles plugged with rubber cork and equipped with valve for biogas measurement. Batch experiments on biogas production were conducted adapting the following treatments.

T_1- Absolute control

T_2- Reeling wastewater + Rumen fluid

T_3- Reeling wastewater + Feed waste + Rumen fluid

T_4- Reeling wastewater + Excreta + Rumen fluid

T_5- Reeling wastewater + Cocoon waste + Rumen fluid

Adjustment of total solids in the test substrates to the desired level of 8% was achieved bysupplementing cocoon waste (60 g), feed waste (30 g) and excreta waste (29 g) to 100 ml of silk reeling wastewater. Rumen fluid collected from abattoir was added @ 5% to all treatments. For absolute control, 100 % rumen fluid was used. All the samples were run in triplicate and biogas production recorded every 48 hrs, till the biogas production ceased. Biogas production was measured by water displacement method(Adamu, 2014)and methane content determined by saccharometer as suggested by (Egneus,

1987). Statistical analysis was done using SPSS 16.0 for windows by which it is possible to evaluate whether the treatments were significant.

RESULTS AND DISCUSSIONS

The silk reeling wastewater had high volatile solid content (37.83%), but very low content in total solids (0.10%). The organic carbon in the silk reeling wastewater was 0.40% and fixed carbon value was 0.1 per cent. The total nitrogen content was appreciably high (0.95%) and C: N ratio was 0.40% (table .1).

The physio–chemical characteristics namely TS, VS, Fixed carbon, Organic carbon, Total nitrogen, C/N ratio of the solid waste is also presented in table 1. Among the treatments, total solids (TS) was high in feed waste (27.4%) followed by excreta (27.14%) and cocoon waste(12.79%). In Poland, (Łochynska, 2018)also have recorded high content of total solids to the extent of 31.87% in silkworm excreta. Plant waste are generally rich in total solids as observed by(Małgorzata, 2017) who recorded TS (25.67%) in banana peel. Total solids of rearing and reeling wastes recorded in this study varied between 12 to 27.4 % which is higher than the optimum value of TS (8-10%) for biogas production reported by (Tomita, 2007).

Volatile solids of the feed waste was about 45.39% which was lower than the value reported by (Łochynska, 2018)of about 79.07% in silkworm excreta. The fixed carbon content of the feed waste was about 1.4% which was higher than the value reported by (Abdullah, 2016)of about 0.1% in corn cob. The total kjeldhal nitrogen was found to vary in the range (1-1.16%) and organic carbon was found to be in the range (36-49%). The C:N ratio was recorded in the range of 33 to 48 which was higher reported by (Yuan, 2013). The range falls in the optimum C: N ratio of 25 to 30 for biomethanation process reported by (Abouelenien, 2009).

The Total solid was adjusted in the silk reeling wastewater to the desired level of 8% by varied substrates was given in the table 2. The characteristics of TS (8%) in wastewater reveal that volatile solids (35-49%), organic carbon (36-40%), fixed carbon (2.4-3.8%) were recorded. About 4.75% of volatile solids, 40.31% of and 3.1% of fixed carbon can be increased in reeling wastewater compared to the solid waste.

Biogas Production from Sericulture Wastes

The biogas productions observed from the treatments are presented in table 3. The maximum biogas production of 2.94 (L/Kg/day) was observed in the treatment T_3 (Reeling wastewater + Feed waste + Rumen fluid) with the substrate to inoculum ratio of 1:0.30:0.05 and TS of 8%followed by 2.65(L/Kg/day) in excreta added wastewater (T_4). As compared to control, biogas production in feed waste, excreta and cocoon waste added reeling water was higher by 9.1, 6.3 and 3.5 % respectively. Liu (2014) also has reported that 5% TS adjusted compressed sewage sludge slurry was higher 1.58 (L/Kg/day) as compared against TS poor in uncompressed sewage sludge. Not only silk reeling wastewater, but other industrial wastewater added plant wastes also reported higher biogas production. (Deshmukh, 2012), in his work on distillery wastewater added *Ipomoea carnea*, observed higher biogas production (2.52 L/Kg) when compared to the biogas production from distillery wastewater alone (1.56L/Kg).(Mahanta, 2004)have also reported that maintaining 8% TS in cattle dung fed digesters fetches more biogas (13.01 L in 55 days) compared to 2.5% (7.34 L) and 12 % (6.82). They concluded that maintaining reactor temperature of 40^{o}C is suitable for low TS wastes and mesophilic temperature maintained reactors are suitable for wastes having more than 8% TS. In this study also, the experiment was conducted at mesophilic temperature conditions (room temperature).

With respect to the number of days of biogas production, highest biogas production was recorded on fourth day in T_3 (0.49 L/Kg of feed) and T_4(0.34 L/Kg of feed), while in all other treatments biogas production peaked on the 6th day (table 3). With respect to the rate of biogas production, the biogas production in T_1 and T_2 increased gradually during the experimental period till 6th day, whereas in T_3, T_4 and T_5 the production suddenly peaked on fourth day itself and declined there onwards. In Kitchen waste, (Yuan, 2013), recorded peak biogas production on 8th (0.12 L/Kg/day), after which it declined to stop on 16th day. This trend was more or less observed in this study also, where in biogas production stopped on 16th day in T_1, T_4 and $T_{5,}$ whereas, in T_2 and $T_{3,}$ biogas production stopped on 18th day (figure 1). On the whole, the gas production in all treatments was recorded high on the 6th day, except for T_3 and T_4, which recorded better gas output than the other treatments. It reveals that, with rumen fluid as activator, the substrate quantity of 100 ml gets quickly acted upon by anaerobes in the first week itself under liquid state fermentation (table 5).

All the three TS adjusted treatments produced biogas with methane content of above 60 per cent (table 4). While the methane content of biogas produced in the treatment T_3accounted for 67%, T_{5} - cocoon waste with waste water also produced biogas with methane content of 65.2 per cent. In T_2, 64% was the methane content. Studies on anaerobic digestion of silkworm pupae conducted by Viswanath, (1994) at Mysore, also revealed methane (67%) rich biogas production. Silkworm pupae constitutes 55.6% protein content on total weight basis and hence can induce biogas production (Omotake, 2010). In liquid state fermentation of paddy leaf waste (straw) also, (Gnanambal, 2015)recorded higher methane content (68%) in 21 days. Straw being a rich in ligno-cellulosic biomass, could yield biogas with more than 65% methane, reported (Howard, 2003). The methane production was peaked high in T_3, $T_4$and T_5 on the 8th day and gradually declines from 10th day onwards, whereas T_1(54.9%) and T_2(58.1%) methane content was recorded high in 10th day and starts declined there onwards. After the 10th day, methane content drastically reduced below 60%in all treatments indicating exhaustions of feed stock for anaerobic digestion.

CONCLUSIONS

From the experiments conducted, it could be concluded that the sericulture reeling wastewater can be effectively put into use for biogas production after increasing the TS to 8% by mixing with mulberry feed waste and using rumen fluid as inoculums with 67% methane content.

Table 1: Physio-Chemical Characteristics of different Sericulture Wastes

Parameters	Reeling wastewater	Cocoon waste	Leaf waste	Excreta
Total solids (%)	0.10	12.79	27.41	27.14
Volatile solids (%)	37.83	37.02	45.39	43.69
Organic carbon (%)	0.40	36.13	49.09	43.63
Fixed carbon (%)	0.10	0.80	1.40	1.20
Total nitrogen (%)	0.95	1.06	1.16	1.10
C/N ratio	0.40	33.90	48.3	41.06

Table 2: Characteristics of TS (8%) adjusted Sericulture Wastewater

Parameters	RWW + Feed waste	RWW+ Excreta	RWW + Cocoon waste
Total solids (%)	8.00	8.10	7.90
Volatile solids (%)	42.48	39.63	35.40
Organic carbon (%)	40.72	39.11	36.54
Fixed carbon (%)	3.80	3.60	2.40
Total nitrogen (%)	1.10	1.26	1.30
C/N ratio	37.01	32.5	27.68

Table 3: Biogas Production (Batch Process) using different Sericulture Wastes

Treatments	Biogas Production (L/Kg of feed) in days									
	2	4	6	8	10	12	14	16	18	20
T_1	0.07	0.15	0.25	0.21	0.10	0.07	0.03	0.01	0.00	0.00
T_2	0.04	0.11	0.25	0.24	0.10	0.08	0.06	0.04	0.01	0.00
T_3	0.23	0.49	0.37	0.23	0.22	0.09	0.01	0.02	0.00	0.00
T_4	0.28	0.34	0.26	0.17	0.10	0.07	0.04	0.01	0.00	0.00
T_5	0.25	0.32	0.16	0.19	0.12	0.09	0.05	0.01	0.00	0.00

Table 4: Methane content of Biogas Produced using Sericulture Wastes

Treatments	Methane Content (%)									
	2	4	6	8	10	12	14	16	18	20
T_1	12.0	25.2	37.9	43.0	54.9	46.2	39.5	30.0	17.3	0.0
T_2	20.6	31.5	45.1	56.2	58.1	43.8	37.0	20.8	14.4	0.0
T_3	40.5	56.6	64.0	67.0	59.0	45.4	31.5	22.6	6.6	0.0
T_4	32.9	40.5	51.5	64.5	60.2	56.5	29.9	15.8	3.0	0.0
T_5	38.7	47.8	56.2	65.2	60.3	53.2	36.5	27.8	14.2	0.0

Table 5: Total Biogas Production (L/Kg of feed) and Average Methane Content (%) of Sericulture Wastes

Treatments	Total Biogas Production (L/Kg of feed)	Average Methane (%)
T_1	1.88	30.60
T_2	2.03	32.75
T_3	2.94	39.32
T_4	2.66	35.48
T_5	2.38	39.99

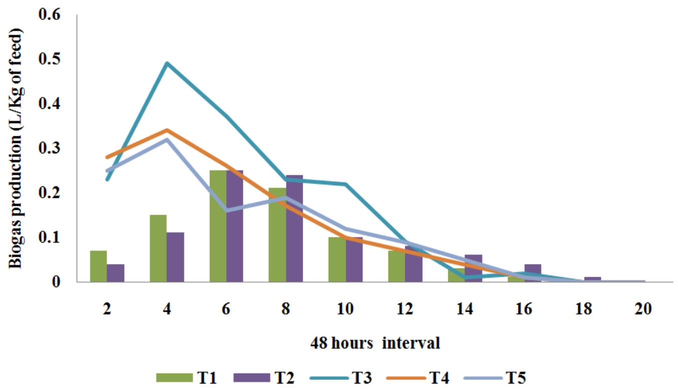

Figure 1: Biogas Production (L/Kg of feed) in Sericulture Feedstock

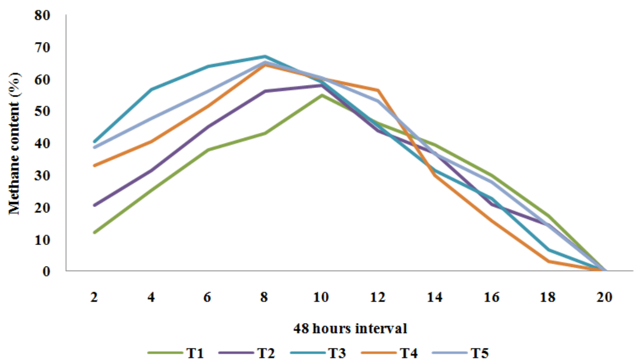

Figure 2: Methane Content (%) of Treatments in Batch Study

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